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13. ABSTRACT *(Maximum 200 words)*

Gravity can be measured on the sea surface and on the seafloor. Surface gravity suffers from lack of resolution over deep seas, because the perturbing source masses are far from the meter. Bottom measurements recover this resolution, but suffer from poor coverage because of the time needed for individual measurements. Our proposed solution to this problem is a towed deep-ocean gravity meter (TOWDOG), which combines the rapid data collection of shipboard measurements with resolution approaching ocean bottom measurements. The near-bottom gravity measurements have the advantages of both existing techniques while avoiding the problems inherent in each one.

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Deployment of the Towed Gravity Meter

Final Report

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Long-Range Objectives

Gravity can be measured on the sea surface and on the seafloor. Surface gravity suffers from lack of resolution over deep seas, because the perturbing source masses are far from the meter. Bottom measurements recover this resolution, but suffer from poor coverage because of the time needed for individual measurements. Our proposed solution to this problem is a towed deep-ocean gravity meter (TOWDOG), which combines the rapid data collection of shipboard measurements with resolution approaching ocean bottom measurements. The near-bottom gravity measurements have the advantages of both existing techniques while avoiding the problems inherent in each one.

While gravity methods have been used on land for several decades to further our understanding of earth structure, we are just beginning to bring the power of gravity field quantification to constructing detailed models of the crust underlying the ocean. Our work focuses on the development of gravity measuring and interpretation tools that can be applied to undersea structures such as seafloor volcanoes and mid-ocean ridges. Rather than relying on the standard marine gravimetric methods, we wish to lengthen the list of tools available to the marine geophysicist for applying gravity measurements to understanding the makeup of the crust beneath the oceans.

Work Completed: Emery Knoll and the San Diego Trough

Two surveys were done with the TOWDOG. The more recent of these was over Emery Knoll, a seamount near San Clemente Island in the California Borderlands. Data from this survey have been reduced and analyzed—final integration with seismic records is currently underway.

Analysis and interpretation of the first survey has been completed. This was over the San Diego Trough, a flat, elongated, sediment-filled basin about 35 km offshore of San Diego, California.

Navigation is now accomplished by a dynamic model of the towing cable which takes into account the weight and drag of the cable and instruments. Use of this model resulted in a definite improvement to the repeatability of the gravity recorded by collocated towed tracks, particularly in tracks traveling in opposite directions. Comparison of the cable model positions to those derived from a limited set of transponder data shows the navigation may have a cross-track error of up to 300 meters. Comparison of the bathymetry recorded by the rock-scan sonar to that recorded by the ship sonar indicates an along-track error of

about 100 meters. Despite these estimated errors in position, the gravity has a repeatability of 0.4 mGal between collocated tracks, with a coherency of 0.8 or better for wavelengths longer than 650 meters.

Results

One of the purposes of the San Diego Trough survey, in addition to testing the instrument, was to determine if a significant density contrast occurs in the near-surface sediments across the San Diego Trough fault. Another was to use the towed gravity data to develop an integrated geophysical interpretation of the region around the location of the survey lines. In order to accomplish this, the San Diego Trough towed data were combined with surface gravity, magnetic and seismic reflection data. The seismic data were proprietary multi-channel sections obtained from the Mineral Management Service in Camarillo, CA. They indicate a deep (3 to 5 km below s.l.) sedimentary basin directly overlying acoustic basement (the Catalina Schist) on the western flank of the basin. On its eastern side, under the Coronado Bank, the reflection data indicate a3-part model: flat, young sediments, an older, lithified and deformed sedimentary rock layer, and underlying acoustic basement (igneous or metamorphic rock, but sedimentary rocks are not ruled out). Densities for the basement and the older sedimentary rock were obtained from measured samples and seismic refraction velocities (about 5.5 km/sec for the basement, 2.7 km/sec for the sedimentary rock). A published density/depth function was used to characterize the compaction-with-depth nature of the younger sediments. Using these densities, and the seismic data as a model guide, the towed and surface gravity data were fit using a 2-D forward modeling algorithm. The conclusions from these studies were: 1) No significant near-surface density contrast across the San Diego Trough fault is evident, as the data are fit to within their noise level without appealing to such a contrast. 2) The San Diego Trough basin geometry obtained from interpreting the seismic sections can fit the towed and surface gravity data using the 3-part model described above. Minor departures from the strict seismic interpretation are necessary to better fit the data. 3) The composition of the deep structure of the Coronado Bank may not be uniquely determined from gravity data, as it may be fit using an igneous/metamorphic assumption(density = 2700 kg per cubic meter) or a sedimentary assumption (density = 2500 kg per cubic meter) coupled with an increase in the density of the deeper crust.

Much progress in interpreting the gravity data for the Emery Knoll survey has been made. Seismic reflection profiles over the Knoll were obtained from the USGS and also from the Mineral Management Service as discussed above. A depth-to-basement map was constructed from these profiles. The main structure is the solid body of the uplifted Knoll surrounded by a "rim syncline" of sedimentary rocks. Magnetic data in map form were also digitized from an excellent published aeromagnetic map of the region, and filtered to yield an isolated positive anomaly limited to the region around the central peak of the Knoll. The towed gravity data, when processed to yield a complete Bouguer anomaly, display a gravity high over the central peak, and the definite effect of the surrounding lower-density sediments.

Publications resulting from this research are:

Zumberge, M. A., J. R. Ridgway, and J. A. Hildebrand, A towed marine gravity meter for near-bottom surveys, *Geophysics 62*, 1386-1393, 1997.

Ridgway, J. R., The development of a deep-towed gravity meter, and its use in marine geophysical surveys of offshore southern California, and an aircraft laser altimeter survey of Long Valley, California; a dissertation submitted in partial satisfaction of the requirements for the PhD degree, University of California, San Diego, Nov. 10, 1997.

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FORM A2-2

AUGMENTATION AWARDS FOR SCIENCE & ENGINEERING RESEARCH TRAINING (AASERT) REPORTING FORM

The Department of Defense (DOD) requires certain information to evaluate the effectiveness of the AASERT program. By accepting this Grant Modification, which bestows the AASERT funds, the Grantee agrees to provide the information requested below to the Government's technical point of contact by each annual anniversary of the AASERT award date.

1. Grantee identification data: (R & T and Grant numbers found on Page 1 of Grant)

a. University of California, San Diego
University Name

b. N00014-93-1-0012
Grant Number

c. 4253189---03
R & T Number

d. Mark Zumberge
P.I. Name

e. From: 10/1/92 To: 5/31/96
AASERT Reporting Period

NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement."

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period prior to the AASERT award date.

a. Funding: $ 0

b. Number FTEGS: 0

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month reporting period.

a. Funding: $ 50,400

b. Number FTEGS: 1

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

a. Funding: $ 118,963

b. Number FTEGS: 1

c. Number UGS: .5

VERIFICATION STATEMENT: I hereby verify that all students supported by the AASERT award are U.S. citizens.

Mark A. Zumberge
Principal Investigator

Date